Overview

• Set the Stage – Climate Change

• Overview of Regional Research

• A New Synthesis and Outreach Project
Global Carbon Cycle (in GtC)

- **Vegetation**: 610 GtC
- **Soils and detritus**: 1580 GtC
- **Surface ocean**: 1020 GtC
- **Marine biota**: 3 GtC
- **Dissolved organic carbon**: <700 GtC
- **Intermediate and deep ocean**: 38,100 GtC
- **Surface sediment**: 150 GtC

- Global net primary production and respiration:
  - To Atmosphere: 60 GtC
  - From Atmosphere: 1.6 GtC

- Changing land-use:
  - To Atmosphere: 0.5 GtC
  - From Atmosphere: 90 GtC

- Fossil fuels and cement production:
  - From Atmosphere: 5.5 GtC
Atmospheric Carbon Dioxide Over the Last 1000 Years
Atmospheric Carbon Dioxide over the last 160,000 years and the next 100 years

- CO₂ in 2100 (with business as usual)
- Lowest possible CO₂ stabilisation level by 2100
- CO₂ now
The Greenhouse Effect

Solar radiation

$CO_2$
Variations of the Earth's surface temperature for the past 160,000 years
Climate has changed globally....

- 0.6°C increase in global mean temperature
- Change in magnitude and distribution of precipitation

(IPCC, 2001)
Climate has changed regionally...

✓ 0.4°C increase in mean annual temperature
✓ 4 - 20% increase in mean annual precipitation
✓ Increased variability in both temperature and precipitation

(NERA, 2001)
Indicators of Climate Change
(Tom Huntington et al.)
Indicators of Climate Change
(Tom Huntington et al.)

- Heating Degree Days

8 Sites in ME

[Diagram showing heating degree days for 8 sites in ME with a trend line indicating a decrease over time.]
Indicators of Climate Change
(Tom Huntington et al.)

- Heating Degree Days
- Mean Annual Sea Surface Temperature, Boothbay Harbor, Me
Indicators of Climate Change
(Tom Huntington et al.)

- Heating Degree Days
- Mean Annual Sea Surface Temperature, Boothbay Harbor, ME
- Water Temperature at the Wild River, ME
Indicators of Climate Change
(Tom Huntington et al.)

- Heating Degree Days
- Mean Annual Sea Surface Temperature, Boothbay Harbor, ME
- Water Temperature at the Wild River, ME
- Ice Thickness, Piscataquis River, ME
Indicators of Climate Change (Tom Huntington et al.)

- Heating Degree Days
- Mean Annual Sea Surface Temperature, Boothbay Harbor, ME
- Water Temperature at the Wild River, ME
- Ice Thickness, Piscataquis River, ME
- Day of first bloom, Lilac, NE USA

Indicators of Climate Change in the Northeast 2005

Clean Air - Cool Planet

and

Cameron P. Wake
The Climate Change Research Center,
University of New Hampshire
Climate will continue to change globally....
Climate will continue to change globally....

✓ 1.4 to 5.8 °C increase in mean annual temperature

(IPCC, 2001)
Climate will continue to change globally....

- 1.4 to 5.8 °C increase in mean annual temperature
- Change in quantity and distribution of precipitation

(IPCC, 2001)
Climate will continue to change globally....

- 1.4 to 5.8 °C increase in mean annual temperature
- Change in quantity and distribution of precipitation
- Increased frequency and magnitude of severe weather events including droughts, floods, and **HURRICANES**!

(IPCC, 2001)
Climate will continue to change regionally....

- 3.1 to 5.3°C increase in mean annual temperature
- 10-30% increase in precipitation
- Increased frequency of drought (Canadian Model)
- Greater intra- and inter-annual climate variability

(NERA, 2001)
So what?
Temperature and moisture are two of the fundamental drivers of all chemical and biological processes.
The Research

- Experimental Manipulations
- Gradients
- Biological Observations
- Modeling
Experimental Manipulations

• Temperature

Regional Synthesis

Experimental Manipulations

• Temperature

Experimental Manipulations

• Temperature

20 peer-reviewed papers
1 book
2 book chapters
Experimental Manipulations

- Temperature
Experimental Manipulations

- Temperature
Experimental Manipulations

- Temperature

![Graph showing percent change in N mineralization](image)
Experimental Manipulations

- **Temperature**

![Percent Change in Plant Productivity](chart)
Experimental Manipulations

• Temperature

Soil Respiration at the Harvard Forest
Experimental Manipulations

- Temperature

Soil Respiration at the Harvard Forest

![Graph showing soil respiration over years with disturbance control and heated conditions.](image-url)
Experimental Manipulations

- Temperature
- Moisture

Experimental Manipulations of Soil Moisture at the Harvard Forest
Eric Davidson et al.
Experimental Manipulations

- Temperature
- Moisture
Experimental Manipulations

- Temperature
- Moisture

Harvard Forest Moisture Manipulation
Soil Respiration

Davidson et al.
Experimental Manipulations

• Temperature
• Moisture
Experimental Manipulations

- Temperature
- Moisture

Fig. 5. Response of in situ net nitrification to precipitation change. Bars with different superscripts indicate statistically significant differences within the treatment period at p < 0.05.

Rustad et al.
Experimental Manipulations

- Temperature
- Moisture
Experimental Manipulations

- Temperature
- Moisture
- Snow

Snow Manipulation Experiments in Northeastern North America
Experimental Manipulations

- Temperature
- Moisture
- Snow

Snow Depth Experiments at:
1. Underhill, VT
2. Duchesney Experimental Forest, Quebec
3. Hubbard Brook, NH
4. Harvard Forest, MA
Experimental Manipulations

- Temperature
- Moisture
- Snow

Vermont Snow Depth Manipulation

Decker et al. (2003)
Experimental Manipulations

- Temperature
- Moisture
- Snow

Groffman et al. 2001 Biogeochemistry
Experimental Manipulations

- Temperature
- Moisture
- Snow

Groffman et al. 2001 Biogeochemistry
Experimental Manipulations

- Temperature
- Moisture
- Snow

**HBEF Snow Depth Manipulation**

Mineralization and nitrification (g N m⁻¹ y⁻¹)

Groffman et al. 2001 Biogeochemistry
Experimental Manipulations

- Temperature
- Moisture
- Snow

Tierney et al. 2001 Biogeochemistry
Gradient Studies
Gradient Studies

- Maine Environmental Gradient Study – Fernandez et al.
Gradient Studies

• Maine Environmental Gradient Study – Fernandez et al.

### Table 1

Means and ranges for characteristics of the sites in this study.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean</th>
<th>Range</th>
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<td>Latitude</td>
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<td>Elevation (m)</td>
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<td>Slope (%)</td>
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<td>Basal Area (m² ha⁻¹)</td>
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<td>17 - 40</td>
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<td>Conifer (% Basal Area)</td>
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<td>Mean Annual Air Temperature (°C)</td>
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<td>Mean Annual Soil Temperature (°C)</td>
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<td>Mean May-Oct Air Temperature (°C)</td>
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<td>Mean May-Oct Soil Temperature (°C)</td>
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<td>Frost-Free Days</td>
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<td>Growing Degree Days</td>
<td>2326</td>
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<tr>
<td>Precipitation (cm)</td>
<td>103</td>
<td>90 - 140</td>
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Gradient Studies

- Maine Environmental Gradient Study – Fernandez et al.
Gradient Studies

- Maine Environmental Gradient Study – Fernandez et al.
- Northeastern High Elevation Forest Floor Study - Hanson et al.; Evans et al.
Gradient Studies

- Maine Environmental Gradient Study – Fernandez et al.
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Gradient Studies

• Maine Environmental Gradient Study – Fernandez et al.

• Northeastern High Elevation Forest Floor Study - Hanson et al.; Evans et al.

• Hubbard Brook Environmental Gradient Study – Groffman et al.
Gradient Studies

- Maine Environmental Gradient Study – Fernandez et al.
- Northeastern High Elevation Forest Floor Study - Hanson et al.; Evans et al.
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Gradient Studies

- Maine Environmental Gradient Study – Fernandez et al.
- Northeastern High Elevation Forest Floor Study - Hanson et al.; Evans et al.
- Hubbard Brook Environmental Gradient Study – Groffman et al.

More snow at higher elevation

Higher soil moisture at higher elevation

Less soil freezing at higher elevation
Gradient Studies

• Maine Environmental Gradient Study – Fernandez et al.

• Northeastern High Elevation Forest Floor Study - Hanson et al.; Evans et al.

• Hubbard Brook Environmental Gradient Study – Groffman et al.

Higher soil nitrification at higher elevation

Higher soil NO$_3^-$ at higher elevation
Gradient Studies

- Maine Environmental Gradient Study – Fernandez et al.
- Northeastern High Elevation Forest Floor Study - Hanson et al.; Evans et al.
- Hubbard Brook Environmental Gradient Study – Groffman et al.

Higher soil respiration at lower elevation
Biological Observations
Biological Observations

- Birds and small mammals
Biological Observations

- **Birds and small mammals**

Rodenhouse et al.

Birds vs. Temperature

Mean annual Temperature
Bird abundance/10 ha
Linear (Mean annual Temperature)
Biological Observations

- **Birds and small mammals**

How might climate change affect bird populations?

Directly and indirectly

Rodenhouse et al.
Biological Observations

- **Birds and small mammals**
Biological Observations

- **Birds and small mammals**

  **Climate and Song Bird Populations**

  - Food is more abundant during warm, dry years.
  
  - Distribution of birds will shift towards lower elevations in years with cold spring weather.
  
  - Bird densities will be higher in years where weather conditions lead to synchronous arrival of spring migrants.
  
  - Rate of nest predation:
    - will increase in summers following a mast seed crop in the preceding summer/autumn.
    - will decline when inclement weather depresses nest predator activity.
Biological Observations

- **Birds and small mammals**
- **Forest Insects**
Biological Observations

- **Birds and small mammals**
- **Forest Insects**

Gypsy moth annual life cycle

Spring

Summer

Fall

Winter

Barry Cook et al.
Modeling
Modeling

- PnET

Scott Ollinger et al.

Predicted Net Primary Production (g m\(^{-2}\) yr\(^{-1}\))
Modeling

- PnET

Scott Ollinger et al.
Modeling

- PnET

Scott Ollinger et al.
A New Program on:
Synthesis of Climate Change Research
in Northeastern US and Eastern Canadian Forest Ecosystems

NERC CVC Working Group
Funded by NSRC and NSF RCN
Why Northern Forest Ecosystems?

• The dominant land cover type across much of the Northeastern United States and Eastern Canada

• Provide important ecosystem services, including:
  - Forest Products
  - Tourism
  - Recreation
  - Clean air
  - Clean water
  - Biodiversity
Goals

• Increase communication amongst global change scientists in the northeastern U.S. and eastern Canada

• Synthesize the accumulating research on the response of northern forest ecosystems to climate change

• Make this summary available to policy makers, land and resource managers, stakeholders and the interested public
Approach

- **Phase 1:** a scientific synthesis of climate variability and change research in the region

---

**Climate Variability and Change:**
Consequences for Northern Forest Ecosystems

1. Introduction
2. Historical Record for Past Climate Change within the Region
3. Indicators of Past Climate Change within the Region (lake and river ice-out, river flow timing, phenology, etc)
4. Updated Climate Projections for the Region
5. Current Regional Scientific Efforts
   a. Long-term Monitoring
   b. Gradients (space-for-time substitutions)
      i. Elevational
      ii. Latitudinal
   c. Experimental Manipulations
      i. Temperature
      ii. Precipitation
      iii. Snow
   d. Biological Observations
      i. Birds
      ii. Small mammals
      iii. Insects
      iv. Invasive species
      v. Biodiversity Species Redistribution
   e. Modeling
6. Ecological Implications for Northern Forest Ecosystems
   a. Forest impacts
   b. Water impacts
   c. Biogeochemical impacts
   d. Pests and Pathogens
   e. Interactions with O, N and S deposition, Hg, and fire
7. Future Scientific Research Needs
Approach

• Phase 2: the ‘translation’ of this document for the non-scientific community, as a:

  ➢ Forest Service General Technical Report (GTR)
  ➢ Fact Sheets
  ➢ Web site
## Timeline

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The timeline shows the progress of various tasks over the years 2003/2004 to 2006, with specific milestones marked by X. The tasks include First CVC Meeting, Proposal Planning, Proposal Funded, Initial Planning, Second CVC Meeting, Synthesis Paper Writing, Third CVC Meeting, Outreach Paper Writing, and Final Products.
Final Thought....

It is hoped that these products will be used to provide an unbiased scientific basis for forestry related policy and land management decisions within the region.